IJCOM 2023 July;3(1):9-16

Relationship between Total Flight Hours and Individual Factors with Low Back Pain in Indonesian Military Helicopter Pilots

Fazlin Khuzaima[1], Retno Wibawanti[2], Agus Sugiharto[2], Wawan Mulyawan[2], M. Ilyas[2], Dewi. S. Soemarko[2]

[1]Master of Occupational Medicine, Faculty of Medicine, University of Indonesia
[2]Department of Community Medicine, Faculty of Medicine, University of Indonesia

*Corresponding address: Fazlin Khuzaima
E-mail : *fazlinkhuzaima27@gmail.com*

Abstract

Introduction: Helicopter pilots are potentially at risk of Low Back Pain (LBP) and are twice as likely as fighter pilots to experience it. Helicopter pilots' LBP is caused by a combination of risk factors: engine and rotor vibration, ergonomic risks due to cockpit design, static seating position due to operations, and individual factors. These factors are incorporated into cumulative aviation risk exposure, which can be measured by total flight hours. The prevalence of LBP in Caucasians is high, at 50.5%-92%. However, there has not been any research on Indonesian military helicopter pilots who have a different posture from Caucasians.
Objective: To determine the prevalence of LBP, to analyze the relationship between total flight hours and individual factors (age, height, BMI, exercise habits, and smoking habits) with LBP in Indonesian military helicopter pilots.
Methods: The study was conducted at the Indonesian Army and Indonesian Air Force with total sampling method as many as 124 people. An explanation was carried out followed by filling in the consent to become a research subject, filling in personal data, anamnesis, Numeric Rating Scale (NRS), physical examination, neurological examination, and total flight hour data.
Results: There were 124 subjects, consisting of 37.9% pilots and 62.1% copilots, 87.9% of pilots operate large helicopters, have average total flight hours of 450 hours, age of 30 years, the height of 172.66 cm, low intensity exercise habits of 61.3%, and smokers as much as 45.2%. A total of 57 people (46%) experienced LBP. Statistical results showed that total flight hours had an association with LBP (p = 0.035) where each 1 unit increase in total flight hours had a 1.02 times greater chance of LBP.
Conclusion: The prevalence of LBP is 46% and there is an association between total flying hours and LBP in Indonesian military helicopter pilots.
Keywords: total flight hours, LBP, Indonesian military helicopter pilots

Abstrak

Pendahuluan*: Pilot helikopter berisiko mengalami Nyeri Punggung Bawah (NPB) dan berpeluang 2 kali lebih besar dibanding pilot jet tempur. NPB pilot helikopter diakibatkan gabungan faktor risiko, yaitu getaran mesin dan rotor, risiko ergonomi akibat desain kokpit, posisi duduk statis akibat pengoperasian, dan faktor individu. Faktor tersebut tergabung dalam paparan risiko kumulatif penerbangan, diukur dengan jam terbang total. Prevalensi NPB pada kaukasia cukup tinggi, sebesar 50,5%-92%. Namun belum ada penelitian pada pilot helikopter militer Indonesia yang memiliki postur berbeda dari kaukasia.*
Tujuan*: Mengetahui prevalensi NPB, menganalisis hubungan jam terbang total dan faktor individu (usia, tinggi badan, IMT, kebiasaan olahraga, kebiasaan merokok) terhadap NPB pada pilot helikopter militer Indonesia.*
Metode*: Penelitian dilakukan di TNI AD dan TNI AU dengan metode total sampling sebanyak 124 orang. Dilakukan penjelasan dilanjutkan pengisian persetujuan menjadi subjek penelitian, pengisian data diri, anamnesa, Numeric Rating Scale (NRS), pemeriksaan fisik, pemeriksaan neurologis serta data jam terbang total.*
Hasil*: Subjek 124 orang, terdiri dari 37,9% pilot dan 62,1% kopilot, 87,9% mengoperasikan helikopter besar, jam terbang total rata-rata 450 jam, usia 30 tahun, tinggi 172,66 cm, kebiasaan olahraga intensitas rendah 61,3%, dan perokok sebanyak 45,2%. Sejumlah 57 orang (46%) mengalami NPB. Hasil statistik menunjukkan, jam terbang total memiliki hubungan terhadap NPB (p = 0,035) dimana setiap peningkatan 1 unit jam terbang total berpeluang 1,02 kali lebih besar mengalami NPB.*
Kesimpulan*: Prevalensi NPB sebesar 46% dan terdapat hubungan jam terbang total dengan NPB pada pilot helikopter militer Indonesia.*
Kata kunci*: jam terbang total, NPB, pilot helikopter militer Indonesia*

Introduction

The National Institute of Occupational Safety and Health (NIOSH) reports that 1 in 4 (26%) working adults experience LBP. Typically, military helicopter pilots are at twice the risk of developing LBP compared to fighter jet pilots due to cockpit design and helicopter vibration. The prevalence of LBP in military helicopter pilots has been identified by several epidemiologic studies since the early 1960s, ranging from 50.5%-92%.[1] This is a high rate considering that military helicopter pilots are physically trained.

LBP found in the helicopter pilot population is related to flight exposure, characterized as transient pain that tends to be predictable, regular and short-lasting, dull and non-radiating. It arises during flight and ceases sometime after the flight.[2] Gaydos describes the type of LBP in pilots as initial pain during flight or within a few hours of flight, mostly in the upper and lower back area, generally described as dull or aching pain.[3]

LBP in helicopter pilots occurs due to various factors, both extrinsic and intrinsic. Extrinsic factors found from the work environment, in this case, the cockpit, include cockpit design that causes asymmetrical postures, static positions, long sitting positions, and *Whole Body Vibration (WBV). In* addition to extrinsic factors, it is known that intrinsic factors such as physical and psychosocial factors also contribute to causing LBP.

The current helicopter cockpit design, requires *collective* and *throttle* settings with the pilot's left hand, which makes the pilot lean laterally, forward and turn slightly.[4] While the right hand controls the *cyclic* between the thighs, pilots often try to gain more control power on the *cyclic stick* by resting their right forearm on the thigh, forming an angle that is shorter than the optimal angle for good relaxation of the muscle groups in the lumbosacral area.[3] As the pilot's legs control the *pedals*, the flexor muscles in the thigh, foot, and ankle area become continuously contracted.[1] This contraction causes the pelvic position to be pulled by the hamstrings downwards, resulting in a posterior tilt and a lumbar flattening which should be in lordosis (S *shaped* to C *shaped*).[5] Pilots also have to bend forward or called *helo hunch* to see the panel in the cockpit. The *helo hunch* position also keeps the back from resting on the seat.[1]

The complex operation of the helicopter requires all four extremities to be in continuous motion and the pilot sits in an asymmetrical posture during flight. This awkward posture causes the workload of the paraspinal muscles to increase and cause spasm, which compresses the surrounding organs and blood vessels and causes pain. In addition, awkward postures can also cause ligament stiffness, and changes in intervertebral structures such as foramen and intervertebral discs. Epidemiological studies have shown that incorrect posture plays a dominant role compared to vibration in the risk of LBP in helicopter pilots.[6]

The static position during flight also causes local tissue ischemia and flattening in the lumbar region which should be in lordosis. This increases intervertebral disc pressure which contributes to flight-related NPD. As a result, the muscles supporting the spine such as erector spinae, obligue abdominalis, mutifidus, quadratus lumborum, and transversus, will contract repetitively, resulting in muscle *flattening* and spasm that will compress the vascular and nervous system. This causes hypoxia in the muscle tissue and a buildup of lactic acid so that a dull pain sensation appears.[1]

In occupational groups that require prolonged sitting in vehicles such as pilots, posterior pelvic tilt occurs, this position does not provide adequate support to the lumbar spine, resulting in lumbar lordosis and unstable spine position.[7] High levels of lactic acid are also found in the back muscles of workers who are in a sitting position for long periods of time.[8]

Vibrations generated in the engine and rotors are transmitted throughout the helicopter body including into the cockpit and then transmitted through the control levers, floor and seat to the pilot's body resulting in WBV effects.[9] Several studies have shown a *dose-response* relationship between WBV and LBP but none of these studies have shown a clear level of WBV that is safe from the risk of LBP in pilots. As previous research has noted, it is difficult to isolate and evaluate the effects of a single exposure such as vibration when multiple sources of risk are present as is the case in helicopter cockpits.[8] But while WBV is not known to cause LBP in helicopter pilots on its own, it does have an impact by affecting torso stability.[4]

Although work environment factors play a major role in causing a helicopter pilot to experience LBP, many physical and psychosocial factors may be associated with LBP.[3] Some of these individual factors include age, height, BMI, exercise habits, and smoking habits.

Wojtkowiak (2012) found that LBP occurs in older age groups, especially those over 45 years old.[10] This is related to the degenerative process. However, there is no research to suggest that the age of the pilot affects LBP.

In addition to age, height is known to have an influence on the incidence of LBP. Orsello (2013) found that as the height of the pilot increases, the risk of LBP will increase, due to the need for greater bending positions in operating the helicopter. In his study, he stated that male military helicopter pilots had a 9.3% risk of LBP for every 1-inch increase above 71 inches or 180.3 cm. Those who were equal to or taller than 71 inches or 180.3 cm, were shown to be more than twice as likely to experience LBP as those who were below the average height in the study.[11]

BMI has a strong association with LBP in the general population, as increased physical load on the anatomical structures of the spine leads to degenerative changes,[8] but no study has found a link between BMI and LBP in military helicopter pilots.

The use of muscle-specific exercises aimed at improving strength, endurance, flexibility and stabilization of the spine is known to prevent further LBP. This is because overall spinal stability is influenced by the quality and position of the vertebrae, the intrinsic stiffness of the ligaments, and the capacity of the muscles to modulate their tension. A study showed that when undergoing a specific exercise program aimed at improving the strength and endurance of the muscles supporting the spine, the severity of LBP was significantly reduced from 67% to 36%.[1]

Smoking habits can also affect LBP in the general population. Nicotine found in tobacco products is a known vasoconstrictor that will reduce blood circulation, which aggravates the problem of LBP and increases the risk of irreversible tissue damage.[13]

The four extrinsic factors that play a role in the pathomechanics of LBP in helicopter pilots (seat design causing asymmetrical posture, static positioning, prolonged sitting position, and WBV), are incorporated in the cumulative effect of aviation exposure over their career, which is commonly reported and measured as total flight hours.[14] Total flight hours are also often used to represent a snapshot of pilot experience and cumulative exposure risk.[15] Total flight hours can thus represent the duration of exposure to helicopter vibration and inappropriate sitting posture.[4]

The risk of low back pain experienced by helicopter pilots is also reported to increase with the length of service, which is above 11 years and flying hours of more than 1783.4 hours.[16] While research conducted by Gilvan da Silva showed that complaints of LBP began to be experienced by many helicopter pilots after flying hours reached 1190.2 hours.[1] The risk of developing musculoskeletal complaints in helicopter pilots increases rapidly if the flight duration is more than 2 hours or accumulates to more than 20 hours/ week.[17]

From this background, it can be identified that total flight hours, which describe the cumulative effects of a pilot's flight exposure, are closely related to the high incidence of LBP in military helicopter pilots in other countries. Therefore, the authors wanted to determine the prevalence of LBP and the relationship between total flight hours and individual factors (age, BMI, height, exercise habits, and smoking habits) to LBP in Indonesian military helicopter pilots.

Methods

The research design used was the cross sectional method. Total sampling was carried out on 124 military helicopter pilots of the Indonesian Army and Indonesian Air Force who met the inclusion criteria. The research was conducted in July-August 2022. Data collection was carried out by filling in personal data, anamnesis, filling in the Numeric Rating Scale (NRS), physical examination and neurological examination. The drop out criteria in this study are subjects who do not follow the history and physical examination process until completion.

This study was submitted to the Ethics Committee of FKUI / RSCM for review and research approval from the Health Research Ethics Commission of the Faculty of Medicine, University of Indonesia with Number: KET-546/UN2.F1/ETIK/PPM.00.02/2022.

Data obtained from all examination results (interview results, NRS filling, physical examination, neurological examination related to LBP) were then collected and then verified and processed manually using a counting machine and computer. Data analysis was carried out with the *Statistical Package for Social Science (SPSS) 26 for Windows* program, namely the data collected was carried out data cleaning, coding, tabulation and data entered into the computer.

The research was self-funded using private sources.

Results

In this study, the total number of research subjects was 124 people, consisting of 64 Army and 63 Air Force, all of whom were male.

From Table 1, the characteristics of the subjects included an average age of 30.2 years, height of 172.66 cm, total flight hours of 450 hours, and 7 years of service. The jobtask was dominated by copilots (62.1%) and pilots (37.9%), normal BMI (53.2%), low intensity exercise (61.3%), and pilots who smoked (45.2%). Helicopter type was dominated by large helicopters (87.9%). Of the 124 pilots, 57 (46%) experienced LBP.

Table 2 and Table 3 show that total flight hours (p = 0.519, 95% CI 1.00), age, height, BMI, exercise habits, and smoking habits are not associated with LBP in military helicopter pilots (p>0.05).

Table 3 shows that subjects with abnormal BMI who experienced LBP were 46.6% (p = 0.96, 95% CI 0.47-1.94) while subjects with inappropriate exercise habits who experienced LBP were 43.4% (p = 0.579, 95% CI 0.63-2.69), and subjects who smoked and experienced LBP were 50% (p = 0.471, 95% CI 0.66-2.37). Additional analysis data in the form of jobtask, copilots who experienced LBP 49.4% (p = 0.359, 95% CI 0.33-1.45). Pilots who operated large helicopters and experienced LBP were 46.8% (p = 0.784, 95% CI 0.44-

Table 1. Respondent characteristics

Variables	Description n = 124
Total Flying Hours (hours)	450 (580,09-804,98)
Age (years)	30,20 $\pm$ 4,09
Height (cm)	172,66 $\pm$ 4,12
Service Period (years)	7 (7,01-8,67)
IMT	
Abnormal	58 (46,8%)
Normal	66 (53,2%)
Exercise Habits	
Low Intensity	76 (61,3%)
High Intensity	48 (38,7%)
Smoking Habit	
Smoking	56 (45,2%)
No Smoking	68 (54,8%)
LBP	
Pain	57 (46%)
No pain	67 (54%)
Jobtask	
Pilot	47 (37,9%)
Copilot	77 (62,1%)
Helicopter Type	
Large	109 (87,9%)
Small	15 (12,1%)

Table 2. Relationship between total flight hours, age, and height to LBP

Variables	OR (95% CI)	P-value
Total Flight Hours	1,00	0,519*
Age	1,03 (0,95-1,13)	0,466
Height	0,93 (0,85-1,01)	0,104*

3.96). It was concluded that there was no relationship between BMI, exercise habits, smoking habits, *jobtask*, and helicopter type on LBP in military helicopter pilots in this study.

From Table 4, a multivariate test was conducted and it was found that total flight hours had an association with LBP in military helicopter pilots (p = 0.035, 95% CI 1.024), meaning that every 1 unit increase in flight hours increases the risk of NPB by 1.03 times.

Discussion

Of the 124 subjects, all were willing to complete all stages of the study. A total of 46% of the total population experienced LBP. The prevalence of LBP in this study was lower when compared to other countries such as Australia, the UK, and Israel. The posture factor of the Indonesian people, which is relatively smaller than the Caucasoid race, which generally has a tall posture, is quite beneficial, because the tall posture of military helicopter pilots causes the need for a *helo hunch* position during helicopter operations to be greater. The hunched position itself is known to cause a higher risk of LBP and even in the long term can cause muscle weakness.[18]

The subjects in this study had an average age of 30.2 years, of which 1 person was over 40 years old and 123 people were under 40 years old. In hypothesis testing, there was no relationship between age and LBP in military helicopter pilots. Based on theory, musculoskeletal degenerative changes in the spine occur starting at the age of 40 years.[14] Before the age of 40,

Table 3. Relationship of BMI, exercise habit, and smoking habit to LBP

Variables	LBP		Total	OR (95% CI)	P-value
	Yes n (%)	No n (%)			
IMT					
Abnormal	27 (46,6%)	31 (53,4%)	58	1,000 (0,47-1,94)	0,96
Normal	30 (45,5%)	36 (54,5%)	66		
Total	57 (46%)	67 (54%)	124		
Exercise Habits					
Low Intensity	33 (43,4%)	43 (56,6%)	76	0,579 (0,63-2,69)	1,30
High Intensity	24 (50%)	24 (50%)	48		
Total	57 (46%)	67 (54%)	124		
Smoking Habit					
Yes	28 (50%)	28 (50%)	56	0,471 (0,66-2,73)	1,3
No	29 (42,6%)	39 (57,4%)	68		
	57 (46%)	67 (54%)	124		
Jobtask					
Pilot	19 (40,4%)	28 (59,6%)	47	0,67 (0,33-1,45)	0,359
Copilot	38 (49,4%)	39 (50,6%)	77		
	57 (46%)	67 (54%)	124		
Helicopter Type					
Large	51 (46,8%)	58 (53,2%)	109	1,320 (0,44-3,96)	0,784
Small	6 (40%)	9 (60%)	15		
	57 (46%)	67 (54%)	124		

Table 4. Multivariate test

Variables	aOR	95% CI	P-value
Total Flight Hours	1,024	1,002-1,047	0,035*
Height	1,014	0,879-1,170	0,847
Total Flying Hours * Height	1,000		0,033*

musculoskeletal complaints generally arise due to other factors such as work factors and other individual factors. The work environment faced by helicopter pilots with non-ergonomic cockpit design and complex helicopter operations causes pilots to constantly be in awkward positions, static, prolonged sitting, plus vibration exposure during flight. It can be concluded that postural factors are more influential in subjects who experience LBP at a young age. In addition, in Indonesian Army personnel are promoted to structural positions that cause them to be temporarily or even permanently inactive from flying at a certain age. So that at the age of over 40 years, where usually degenerative processes begin to occur, exposure from occupational factors has been reduced because the pilots occupy structural positions.

Height in this study was also found to be unrelated to LBP. Based on research by Orsello (2013), height is known to be a predictor of LBP in helicopter pilots, pilots with a height of more than 71 inches (180.3 cm) are at risk of LBP, with an increase of 1 inch increasing the risk of LBP by 9.3%, this is due to the higher the height of a pilot, the need to bend during helicopter operations will be higher.[11] Whereas in this study, it was found that the average height of the subjects was 172.66 cm. With a lower posture, the need to bend over to reach the operational lever is also reduced.

A total of 58 people had abnormal BMI. In this study, BMI was not associated with LBP. In the Army population, muscle mass is greater than the general population, so BMI cannot be a benchmark for nutritional status of the military population.

It is known that exercise habits in the research subjects, namely 76 people exercising inappropriate (low intensity). Da Silva (2018) states that general physical condition is not an important factor in preventing LBP, but the use of muscle-specific exercises aimed at increasing strength, endurance, flexibility and stabilization of the spine can prevent further LBP.[1] Data collection in this study was also conducted in a cross-sectional manner so there is a risk of *recall* bias even though it has been minimized by the guided interview method. Smoking habits in subjects were found to be unrelated to LBP. Data in the form of the number of cigarettes consumed per day as well as the type of cigarette and questions about e-cigarettes were not explored in this study.

Additional analysis data in the form of jobtask (pilot and copilot) was found to have no effect on LBP because both pilots and copilots carry out the same tasks and missions with the same operational levers and work environment conditions. Helicopter type (weight/large and light/small) was also found to have no effect on LBP in this study. Although smaller helicopters allow pilots to control better under normal conditions than larger helicopters whose operation is considered to require greater effort, it seems that it is necessary to analyze the differences in missions and missions.[19]Although smaller helicopters allow pilots to control better under normal conditions than larger helicopters, it seems necessary to analyze the differences in missions or tasks that may affect the incidence of LBP in helicopter pilots in future studies.

In this study, overall there was no relationship between individual factors and the incidence of LBP in military helicopter pilots with a p value >0.05. This is in line with previous research conducted by Bridger (2002) that there is no relationship between total flight hours, height, weight, smoking history, and family history, to LBP in helicopter pilots. He also stated that poor posture and workload were more influential on LBP in helicopter pilots than work environment conditions.[5]

To determine the factors most associated with LBP in helicopter pilots, multivariate tests were carried out by excluding other factors, so that the results showed that there was a significant relationship between total flying hours and the incidence of LBP in military helicopter pilots with a p value of 0.035 ($p < 0.05$), where every additional 1 unit of total flying hours had a

1.027 times greater chance of LBP in military helicopter pilots. This is in line with the findings of Jeo Hyeon (2016) where every increase of 100 total flying hours, increases degenerative changes in the spine.[20]88.2% The increase in total flight hours increases the risk of LBP in helicopter pilots because the longer the pilot is exposed to occupational risks in the form of postural factors and vibration during flight, the greater the risk of the pilot experiencing LBP. However, postural mechanisms are known to play a stronger role than vibration theory.

Limitations

In this study, neither ergonomic position nor vibration measurements were conducted due to limited access to helicopters in the unit due to the very intense schedule and flight training at the time of the study. However, the researcher conducted additional analysis through the type of helicopter. It is known that some of the latest helicopter types have *dampers* to reduce the effects of vibration on the pilot's body, but in this study, it was found that most military helicopter pilots in Indonesia drive more than 1 type of helicopter (multiengine).

In addition, this study used a *cross-sectional* design, so that although several factors were excluded, it could not be determined which variable caused NPB in the respondents first. This type of research has limitations in the form of recall bias. The factor of subject variation that is too homogeneous can also cause the absence of a relationship between risk and effect. Questionnaire filling can be subjective in its filling due to the unwillingness of the subject to convey the actual condition even though the researcher has minimized it by conducting *Informed Consent* and conducting guided interviews.

Conclusion

The prevalence of LBP in helicopter pilots in Indonesia was 46% with a pilot profile consisting of 37.9% pilots and 62.1% copilots, an average flight hour of 450 hours, 30 years of age, 172.66 cm height, 61.3% light/inappropriate intensity exercise habits and 45.2% helicopter pilots who smoke. The prevalence in this study was lower when compared to other countries such as Australia, the UK, and Israel. Postural factors are quite influential on the prevalence of LBP in military helicopter pilots, with the average height of Indonesian military helicopter pilots below the predictor of LBP, so the need for *helo hunch* position is reduced in Indonesian military helicopter pilots.

There is a significant relationship between total flight hours and LBP in helicopter pilots, but no relationship between individual factors (age, height, BMI, exercise habits, and smoking habits) and LBP in Indonesian military helicopter pilots.

Advice

Further research on the factors associated with LBP in military helicopter pilots in Indonesia needs to be conducted using measurement, workstation analysis or experimental methods to find the right type of stretching exercise to prevent LBP in helicopter pilots in the future.

References

1. Silva GV da. Helicopter pilots and low back pain: How to manage the risk factors? Ergon Int J. 2018;2(1):1-11.
2. Andersen K. Transient low back pain among helicopter pilots; Imaging and lumbar trunk muscular endurance. Phys Med Rehabil Disabil. 2017 Oct 6;3(2):1-7.
3. Gaydos SJ. Low back pain: Considerations for rotary-wing aircrew. Aviat Sp Environ Med. 2012;83(9):879-89.
4. Çinar-Medeni Ö, Güzel NA, Erdogan M. The predictors of low back pain in helicopter pilots. Gazi Med J. 2015;26(1):15-8.
5. Bridger RS, Groom MR, Jones H, Pethybridge RJ, Pullinger N. Task and postural factors are related to back pain in helicopter pilots. Aviat Sp Environ Med. 2002;73(8):805-11.
6. Ernsting's Aviation and Space Medicine, 5th Edition. Vol. 58, J Occupational and Environment Med. 2016. e335 p.
7. Ropper AH. Principles of neurology. 8th ed. Massachusetts: Mc Graw Hill; 2005.
8. Kåsin JI, Mansfield N, Wagstaff A. Whole body vibration in helicopters: Risk assessment in relation to low back pain. Aviat Sp Environ Med. 2011;82(8):790-6.
9. Stupar S, Simonović A, Jovanović M. Measurement and analysis of vibrations on the helicopter structure in order to detect defects of operating elements. Sci Tech Rev. 2012;62(1):58-63.
10. Pain B, Polish IN, Transport M, Pilots A. Back pain in polish military transport. 2012;1(18):7-17.
11. Orsello CA, Phillips AS, Rice GM. Height and in-flight low back pain association among military helicopter pilots. Aviat Sp Environ Med. 2013;84(1):32-7.
12. Johnson L, Johnson L. Factors contributing to pain in military helicopter pilots signature redacted signature redacted. Signature redacted Signature redacted by, 2019.
13. Vibration Hazards in the Workplace: The basics of risk

assessment -- occupational health & safety [Internet]. [cited 2020 Aug 26]. Available from: https://ohsonline.com/Articles/2015/02/02/Vibration-Hazards.aspx.
14. T N, KA K, JP A, TC S, BW S. Effects of flight-exposure and age on cervical and trunk musculoskeletal characteristics in army helicopter pilots. Int J Aeronaut Sci Aerosp Res. 2016;3:123-30.
15. Knecht WR. (DOT/FAA/AM-15/3) Predicting accident rates from general aviation pilot total flight hours. Off Aerosp Med. 2015;February.
16. Vera P de. Rotary pilot low back pain in relation to occupational hazards - a case report - military medicine worldwide [Internet]. [cited 2020 May 24]. Available from: https://www.military-medicine.com/article/3697-rotary-pilot-low-back-pain-in-relation-to-occupational-hazards-a-case-report.html.
17. Bliss JP. The International Journal of Investigation of Alarm-Related Accidents and Incidents in Aviation. 2009; (November 2013):37-41.
18. Andrade YN, Andrade YN. An ergonomic evaluation of aircraft pilot seats an ergonomic evaluation of aircraft pilot seats by Embry-Riddle Aeronautical University. 2013;
19. Carlos Collantes. How much does a helicopter weigh? [Internet]. Available from: https://www.aeroclass.org/how-much-does-a-helicopter-weigh/.
20. Byeon JH, Kim JW, Jeong HJ, Sim YJ, Kim DK, Choi JK, et al. Degenerative changes of spine in helicopter pilots. Ann Rehabil Med. 2013;37(5):706-12.